USAGE OF FMI @ BOSCH STATUS & OUTLOOK

> 66 FMI is the preferred model exchange and co-simulation format of Robert Bosch GmbH at system level enabling the exchange of models with internal and external partners using different modelling tools.
>
> — Robert Bosch GmbH on ITEA3 MODELISAR

CHRISTIAN BERTSCH, BOSCH RESEARCH

Usage of FMI at Bosch - status and outlook
The four business sectors of Bosch

| Mobility Solutions | Industrial Technology | Energy and Building Technology | Consumer Goods |

➔ Modelling and simulation are important pillars in our development process
➔ >100 modelling and simulation tools in use, >10 preferred tools
➔ Exchange and co-simulation of models between departments, business units + external partners

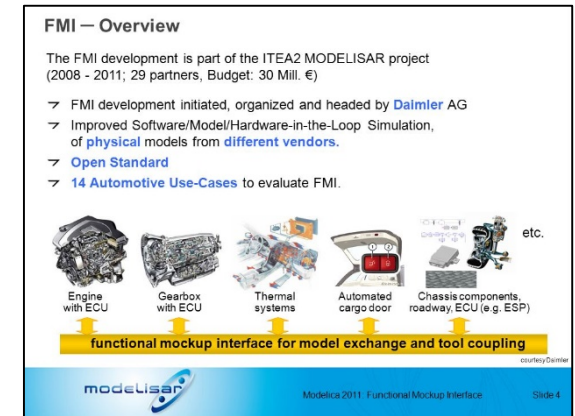**FMI is used in all business sectors of Bosch**

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Usage of FMI at Bosch - status and outlook
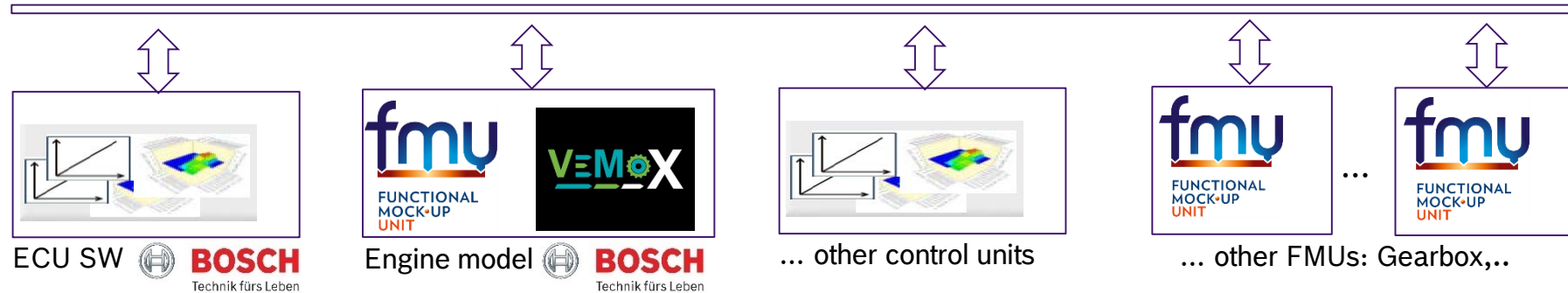## Examples I: FMI usage in automotive

▶ **Vision** of MODELISAR project: Exchange models as FMUs between OEMs and suppliers

▶ **2019:** Collaborative engineering based on FMI is now **reality**: e.g. Software-in-the-Loop Simulation (SiL) for engine control
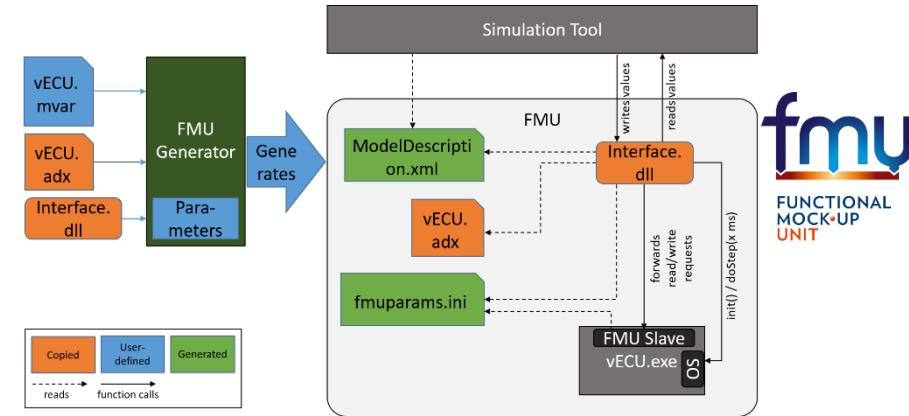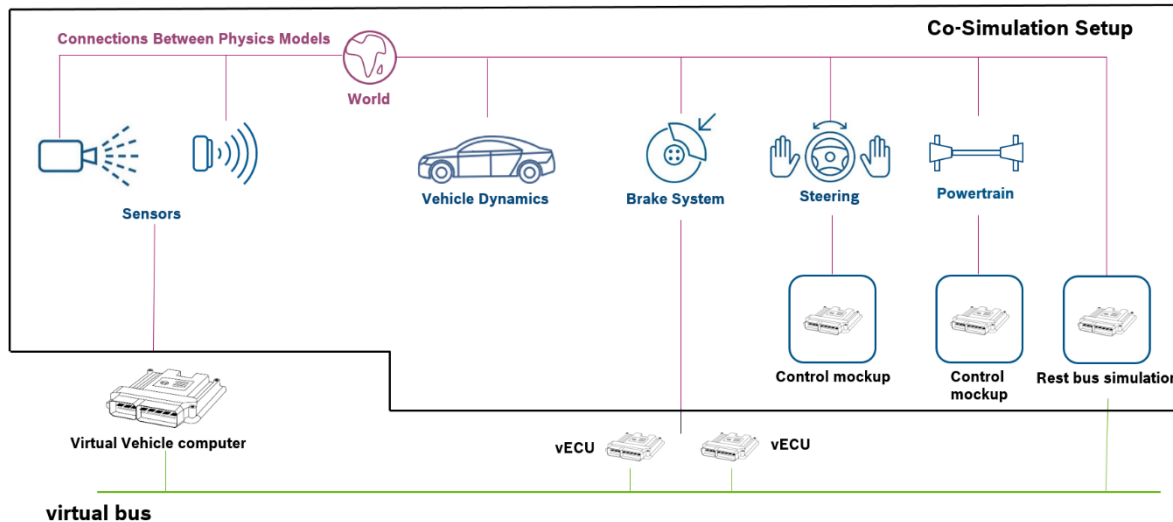
Source: Modelica Conference 2011

DAIMLER

ECU SW | Engine model | ... other control units | ... other FMUs: Gearbox,..

Usage of FMI at Bosch - status and outlook
Example II: virtual ECUs, towards to connected SiL

▶ **Automatic generation of virtual ECUs as FMUs**

▶ Next Step: from virtual ECUs to
**connected SiL simulation including virtual buses**

Source:, P. Baumann, R. Samlaus et. al. A contribution to the simulation of networked virtual ECUs, accepted paper VDI Mechatroniktagung, Paderborn, 2019

ECU = Electronic Control Unit
SiL = software in the Loop

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Usage of FMI at Bosch - status and outlook
Example III: Motion Compensated Mobile Gangway

▶ Development of the drive system of a Motion Compensated Mobile Gangway

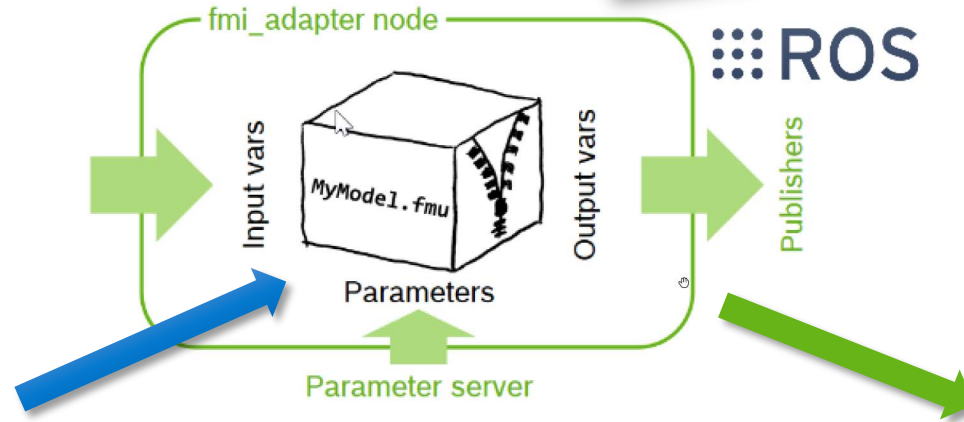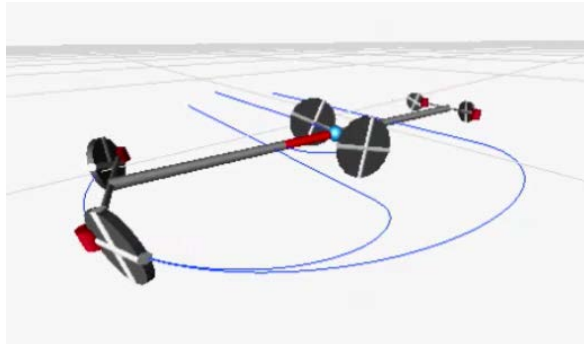▶ Efficient and safe transport of service staff and loads to offshore structures (e.g. offshore wind turbines)
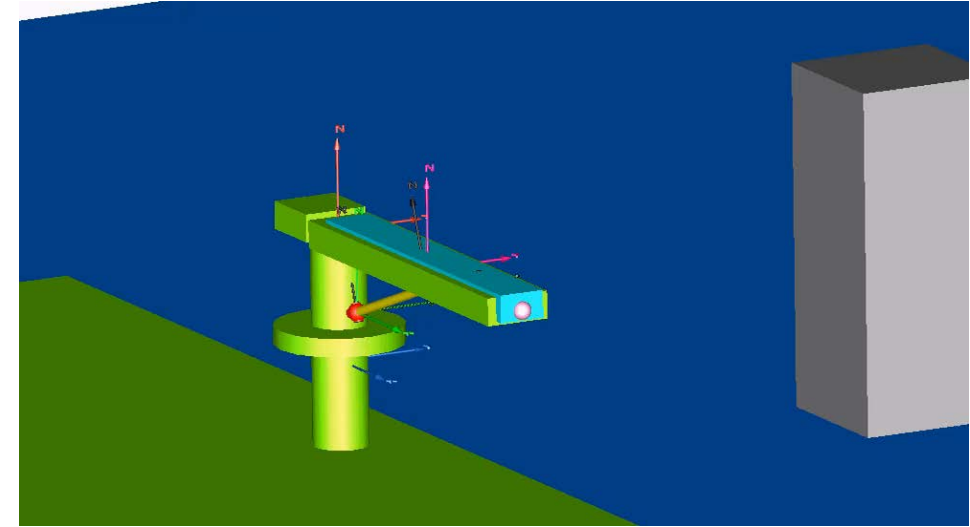
➔ Compensation of ship/wave movement in 3 directions (luffing, slewing, telescoping) up to 3m wave amplitude

➔ **International collaboration across three different locations using different simulation tools. Mechanical models as FMUs.**
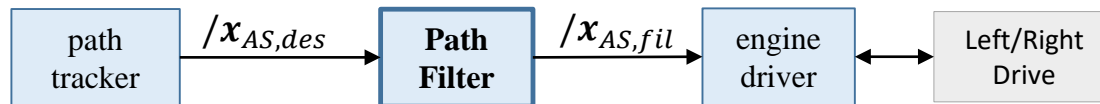
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Usage of FMI at Bosch - status and outlook
Examples IV: Model-based Control in ROS

▶ **Path Filter developed and tested in Modelica MiL**.

▶ **Deployed as FMU to logistic SDV[1] prototype using *FMI adapter* for ROS[2].**

Developed at Bosch Research
Published on Github
https://github.com/boschresearch/fmi_adapter_ros2

ActiveShuttle Dev Kit

fmi_adapter node

∷ROS

Input vars — MyModel.fmu — Output vars

Parameters

Publishers

Parameter server

| path tracker | $/x_{AS,des}$ | **Path Filter** | $/x_{AS,fil}$ | engine driver | ↔ | Left/Right Drive |

Talk on "*Enhanced Motion control of an SDV Using Modelica, FMI and ROS*", by Oliver Lenord, Wednesday 09:30, **Session 4B:** Automotive 2

[1]Self Driving Vehicle
[2]Robot Operating System

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Usage of FMI at Bosch - status and outlook
## Internal FMI activities

▶ **Bosch internal decision:**

    ▶ ***FMI is the preferred model exchange and co-simulation format of Robert Bosch GmbH at system level enabling the exchange of models with internal and external partners using different modelling tools***

▶ **Bosch-internal FMI community with 500 members**

    ▶ Internal social media group

    ▶ Regular expert meetings for exchange on FMI topics

▶ **Bosch-internal FMI Trainings**

    – basic and specialized trainings

    – >200 associates trained

https://openclipart.org/
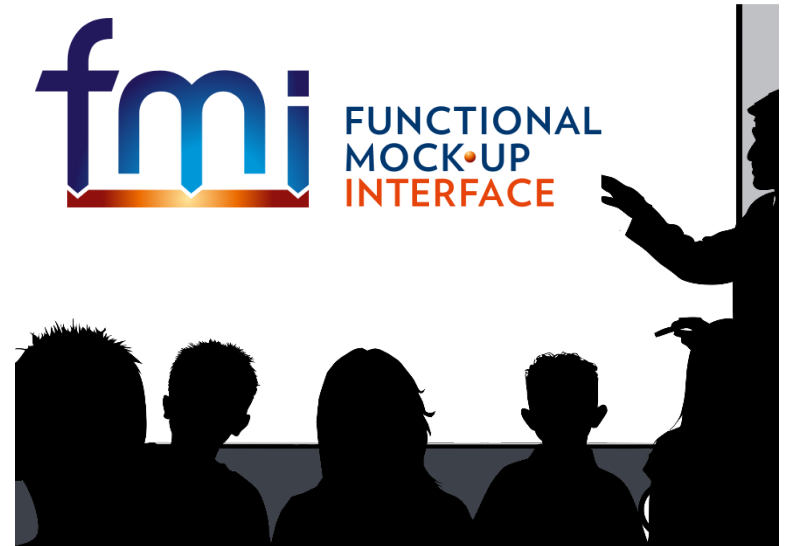
Usage of FMI at Bosch - status and outlook
FMI support in (in-house) tools

▶ **Bosch in-house tools**

  ▶ FMI support in Python toolboxes (via fmpy by Dassault Systems)

  – e.g. for Uncertainty Quantification, model test automation

  ▶ TriboSim (simulation tribological contacts)

  ▶ Generators to wrap ECU-Software as FMUs

  ▶ FMU-adapter for Robot Operating System (ROS): published as open source

  – Released as open source software on Github: https://github.com/boschresearch/fmi_adapter_ros2

▶ **Rexroth in-house tools**

  ▶ Next generation sizing tools

  ▶ SiL simulation of the Bosch Rexroth precision motion control system

▶ **ETAS: FMI support in many tools for embedded Software**

  ▶ SCODE-CONGRA, ASCET, ISOLAR-EVE, COSYM, LABCAR, ASCMO, INCA-FLOW,

Usage of FMI at Bosch - status and outlook
External collaboration within FMI Project

BOSCH ETAS itk

▶ **Member of FMI Steering Committee**

- ▶ Robert Bosch GmbH + subsidiaries ETAS GmbH, ITK Engineering GmbH

▶ Participation in "industrialization" and "stabilization" of FMI

- ▶ E.g., Cross check, Corporate Contributor License Agreement (CCLA)

▶ Contributing to FMI 3.0 development

- ▶ Participation in working groups

▶ Close collaboration with tool vendors:

- ▶ Demanding FMI support preferred simulation tools:
  now almost all have (at least partial) FMI support
- ▶ Piloting FMI support in new tools

2012: Bosch-internal Cross-Check with 4 tools

2019: FMU Cross Check on https://fmi-standard.org/tools/

▶ **Bosch is actively contributing to the development and dissemination of FMI.**

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Usage of FMI at Bosch - status and outlook
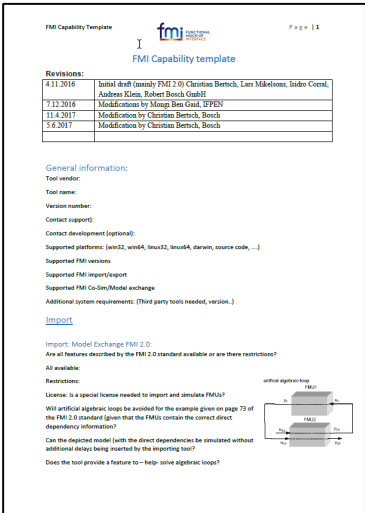## Need for FMI feature overview of tools

▶ **Problem: tools support only certain optional capabilities of the FMI standard.**

▶ The information about these features is hard to find for end users

▶ General tool chains can only rely on commonly supported subset of supported features

▶ **Proposal: Create an overview of FMU features of the tools**

▶ A template for FMI supporting tools to describe the supported features (proposal exists)

▶ Create features support tables, e.g, for FMI 2.0 CS export:

Tool	Can get and set state	Can export source code FMUs	Can export License free FMUs	Can export its standard solvers	Can export FMUs w/o tool dependency
Tool A					
Tool B	✘	✘	✘		✘
Tool C	✘	✘		✘	
Tool D					
Tool E	✘	✘	✘		✘

Proposal: FMI Capability description template

Not in focus of FMI project currently.

Involvement of industrial users needed!

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Usage of FMI at Bosch - status and outlook
Need for FMI 3.0 features at Bosch

▶ **Array support**

　▶ E.g., be used for better support of curves and maps, e.g. in ECU Software

▶ **Binary data type**

　▶ Support sensors for automated driving; clean realization of OSI

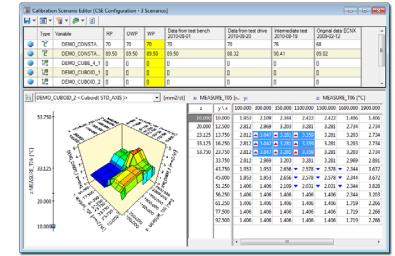　▶ Usage for bus simulation of connected virtual ECUs?

▶ **Intermediate output values**

　▶ Advanced co-simulation schemes for vehicle simulation

▶ **New numerical data types**
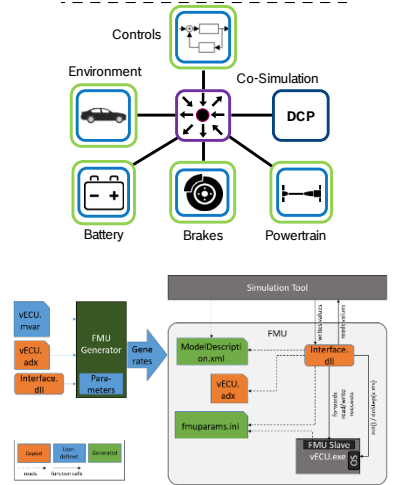
▶ **Clocks and Hybrid Co-Simulation**

　▶ Better support for virtual ECUs, HiL Systems

　▶ Better support for ECU SW wrapped as FMUs
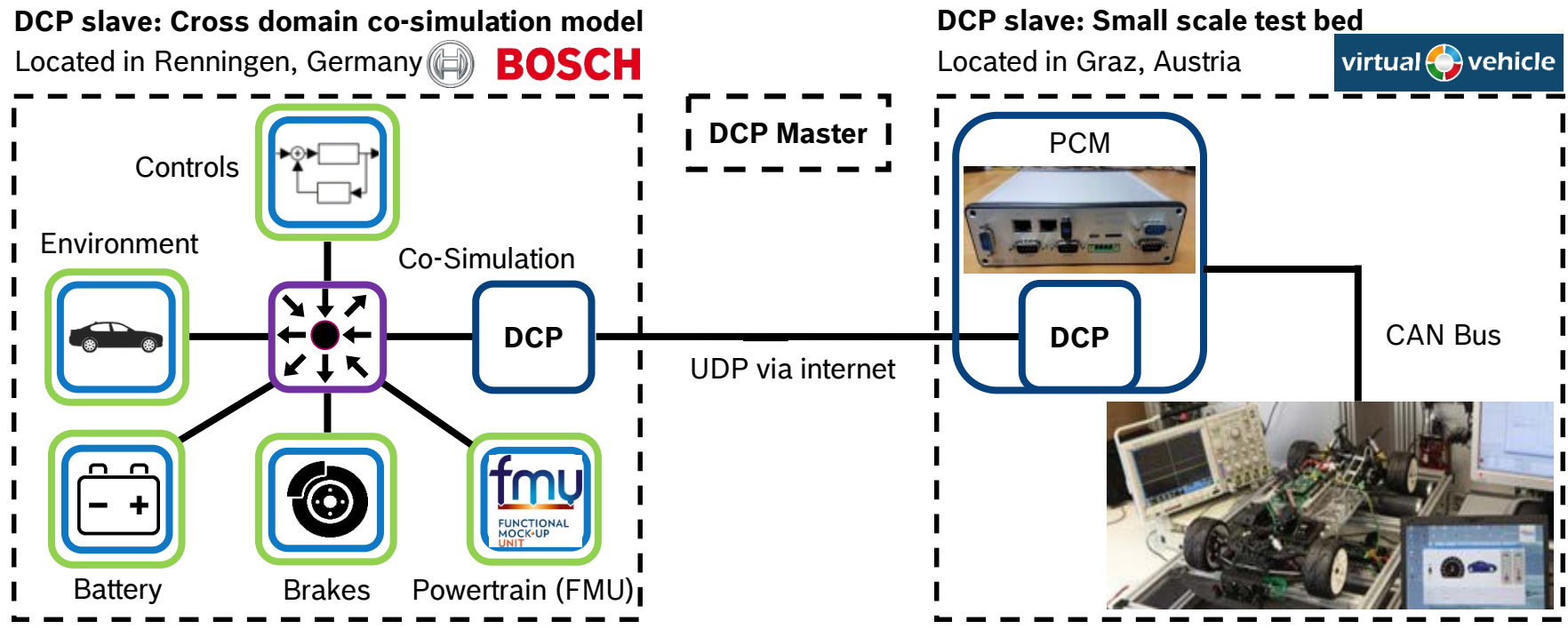

ETAS INCA: Calibrating maps

Source: https://www.pegasusprojekt.de/

CR/AEE3-Bertsch | 2019-02-02 2808　　OSI=Open simulation interface https://github.com/OpenSimulationInterface, HiL=Hardware-in-the-Loop

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Usage of FMI at Bosch - status and outlook
Need for DCP: Distributed realtime simulation with FMI and DCP

DCP slave: Cross domain co-simulation model
Located in Renningen, Germany **BOSCH**

DCP slave: Small scale test bed
Located in Graz, Austria   virtual vehicle

Controls

Environment

Co-Simulation

DCP Master

PCM

DCP

DCP

UDP via internet

CAN Bus

Battery

Brakes

Powertrain (FMU)

fmu FUNCTIONAL MOCK-UP UNIT

Source: https://de.wikipedia.org/

Source: https://de.wikipedia.org/

Peter Baumann et al., Using the Distributed Co-Simulation Protocol for a
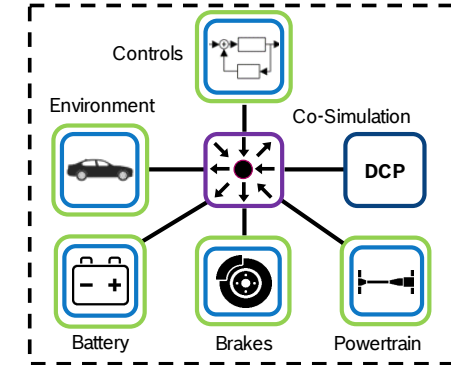*Mixed Real-Virtual Prototype, IEEE 2019 International Conference on Mechatronics, Ilmenau, 2019*

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Usage of FMI at Bosch - status and outlook
Need for SSP standard

▶ **ZF, BMW, Bosch and others initiated SSP standard**
due to the need to

  ▶ Exchange co-simulation topologies in a tool-independent format

  ▶ Exchange and archive parameter sets

▶ Next step: broad and mature tool support needed

  ▶ SSP Compliance Checker and Cross Check Infrastructure

▶ Future work: **extend SSP towards traceability and proof of quality of simulation results**
within PROSTEP Smart Systems Engineering Project

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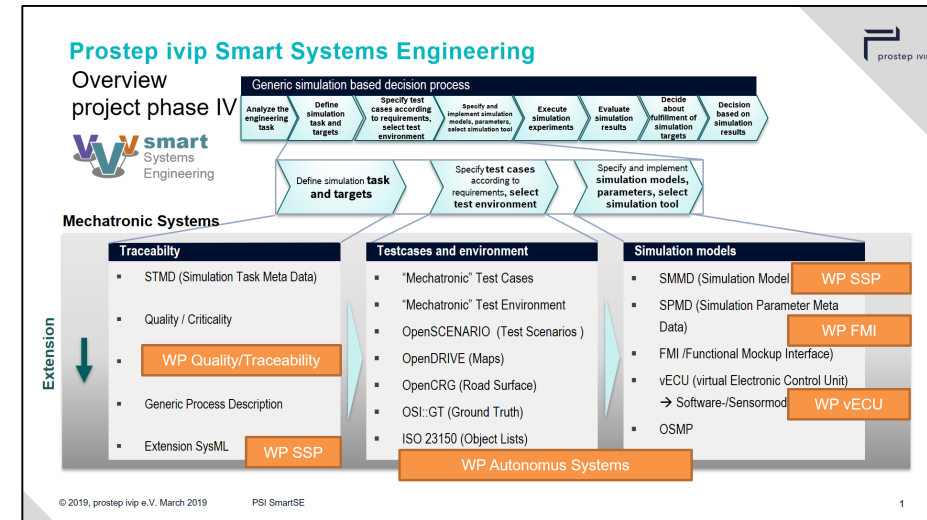
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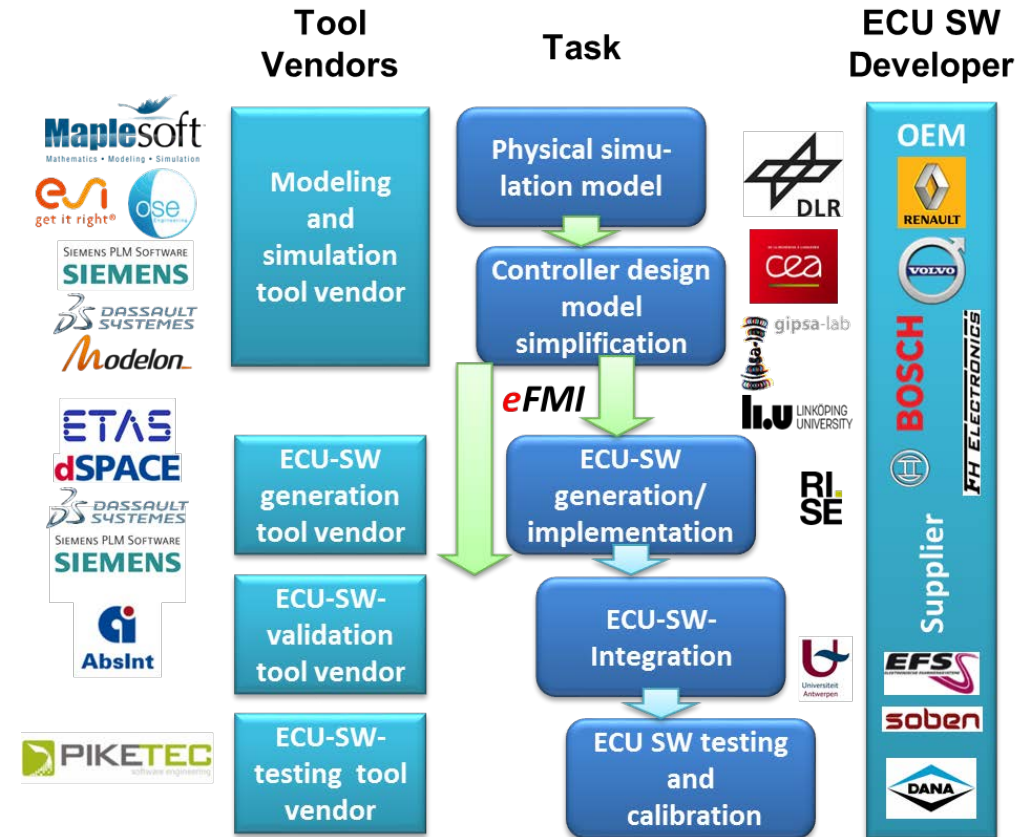## Need to extend FMI towards usage in embedded software

▶ ITEA3 project

▶ Goals:

    ▶ New standard FMI for Embedded Systems (eFMI)

    ▶ Use physical models in control and diagnosis functions in production code of automotive ECUs

Contact: Oliver Lenord (Bosch), Martin Otter (DLR)

25 Partners, 5 Countries, >90PY, 2017 – 2020

THANK YOU.

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